

# ANALYSIS THE PERFORMANCE OF UNSIGNALIZED INTERSECTION BASED ON GAP ACCEPTANCE STUDIES

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## **ABSTRACT**

The main purposed of this study was to analysis the performance of unsignalized intersection based on gap acceptance study. Unsignalized intersection plays an important role in determining the capacity of road network especially in urban and suburban areas. A poorly operating unsignalized intersection may affect a signalized network or operation of an Intelligent Transport System. The T-junction for this study was controls by stop rule or in other names is two-way stop controlled intersection (TWSC). For a TWSC intersection, the stop controlled approaches are referred to as the minor road approaches. The most important parameters affecting the capacity and performance of unsignalized intersection are the critical gap. Basically, critical gap are establish by Highway Capacity Manual. Therefore, the critical gap is difference between each intersection based on the geometry of the road, numbers of lane, and surrounding area located near the intersection. Critical gap can not be determined directly from field but data of accepted and rejected gaps can be collected and analysed. Data of gaps were collected using video camera and several equipments. Raff's method was used in determination of critical gap. In this study, critical gap was divided into three sections which is RT from major road, RT and LT from minor road. The values of critical gap vary from 2 seconds to 7 seconds. Critical gap value that was established by HCM and from field observation was input in Sidra software to analyze the performance of the intersection. Based on analysis of output produced from Sidra software, there is found output were obtained from field observation is more closed with the actual field condition. Therefore, the performance at a TWSC intersection can be determined from this analysis in terms of queue and level of services. This study can be continued in the future in order to improve the value of input parameters and also develop the analysis procedure for four leg intersection and roundabout not only for urban and suburban areas, but also for rural area.

## ABSTRAK

Tujuan utama kajian ini adalah untuk menganalisis prestasi persimpangan tanpa lampu isyarat berdasarkan pada kajian sela kritikal. Persimpangan tanpa lampu isyarat memainkan peranan yang penting dalam menentukan keupayaan suatu rangkaian jalan terutamanya di kawasan bandar dan pinggir bandar. Persimpangan tanpa lampu isyarat yang beroperasi secara tidak teratur boleh menjejaskan sesuatu rangkaian atau operasi sesebuah sistem pengangkutan pintar. Simpang T yang dipilih dalam kajian ini adalah dikawal oleh papan tanda berhenti. Parameter yang paling penting dan memberi kesan pada keupayaan persimpangan tanpa lampu isyarat ini adalah sela kritikal. Pada dasarnya, Highway Capacity Manual telah mengeluarkan nilai sela kritikal bagi persimpangan tanpa lampu isyarat ini. Walaubagaimanapun, nilai kritikal adalah berbeza bergantung kepada bentuk geometri sesebuah persimpangan tersebut. Sela kritikal tidak boleh ditentukan secara langsung daripada lapangan tetapi data sela terima dan sela ditolak boleh dicerap dan dianalisa. Data ruang ini dicerap menggunakan kamera video dan beberapa peralatan lain. Dalam menentukan sela kritikal, kaedah Raff telah digunakan. Dalam kajian ini, sela kritikal dibahagi kepada tiga iaitu pembelokkan kanan dari lorong major, pembelokkan kanan dan kiri dari lorong minor. Didapati sela kritikal adalah berbeza-beza iaitu dari dua hingga tujuh saat. Nilai sela kritikal yang dikeluarkan oleh HCM dan daripada pemerhatian di tapak kajian dimasukkan ke dalam perisian Sidra untuk menentukan keupayaan persimpangan tanpa lampu isyarat ini dari segi panjang kenderaan beratur dan tahap perkhidmatan. Berdasarkan keputusan yang dikeluarkan oleh perisian Sidra, didapati keputusan yang menggunakan nilai kritikal daripada pemerhatian di lapangan adalah lebih dekat dengan keadaan sebenar di persimpangan kajian tersebut. Seterusnya, tahap keupayaan perkhidmatan persimpangan ini dapat ditentukan.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Study

The rapid development of Malaysia increases the cost of living of the citizen especially in urban area. Transportation is also affected by the development and show the annual increase in the number of vehicle. Because of the increasing of vehicle, road congestion and accidents is occurred especially during peak hour. Traffic congestion is a condition on road networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. Intersection plays an important role in the road network, where traffic flows in different direction converge. There is various type of intersection such as at-grade intersection, signalized intersection, unsignalized intersection and roundabout. However, the scope of study is only focused in analysis for the unsignalized intersection. Unsignalized intersection is a common type of intersection to control the movement of the traffic especially in urban area. A poorly operating unsignalized intersection may affect a signalized network or operation of an Intelligent Transport System. Concerning vehicle movement in intersections, there will be a number of conflicts, which influence traffic safety. The most common way to resolve such conflicts is by introducing priority controls such as give way or stop rule at the unsignalized intersection. The rules are implemented at T-intersection or 4-way junction. In Malaysia, majority of the unsignalized intersections is of the T-intersection. Most of the 4-way unsignalized intersections are either converted to signalized intersection.



There are many problem are appeared at the intersection such as congestion, queues, delay and also accident. The evaluation of capacity at unsignalized intersection is practically measured using the gap acceptance approach and used for unsignalized intersection procedure. In this study, the gap acceptance approach was used for unsignalized intersection procedure. The critical gap is a major parameters need to be considered to analysis the unsignalized intersection. In Malaysia, the critical gap for an unsignalized intersection is proposed by Highway Capacity Manual. Therefore, the critical gap is difference between each intersection based on the geometry of the road, numbers of lane, and surrounding area located near the intersection. The efficiency of the performance at unsignalized intersection is become worst if the problem such as delay, queue is always occurred.

Because of such issue, it is necessary to study the intersection in order to analyze the traffic networks and improve the performance of the intersection to solve the identify problems. For this study, aaSIDRA or Sidra Intersection software was used to analyze the performance of unsignalized intersection. Sidra means signalized and unsignalized intersection design and research aid. It has been popular professional tool for traffic engineers and planners worldwide in analysis the performance of the intersection either unsingnalized or signalized. It is appears to be more a popular and effective analytical tool in modeling and analyzing at micro level. It is micro analytical software develops by Akcelik & Associates Pty Ltd. It uses detailed analytical traffic models with an iterative approximation method to analysis the performances of intersection (Azlina Ismail, 2010).

## 1.2 Problem Statement

This study was conducted to analyze and evaluate the performance of unsignalized intersection based on gap acceptance studies. Semambu is one of the urban areas because the population in the area is above 1000 persons. Study location of the intersections is located at Jalan Semambu, Kuantan which is a major road and Lorong Semambu Baru 40 is a minor road of the intersection. The unsignalized intersection was identified as two-way stop controlled unsignalized intersection (TWSC) where the traffic flow was controlled by stop rule. For a TWSC intersection, the stop controlled approaches are referred to as the minor road approaches. Two-way stop control requires the vehicle drivers on the minor streets should see that the conflicts are avoided.

The identified TWSC intersection was located at commercial area, industrial area, and education area such as Sekolah Kebangsaan Semambu. This is shown in Figure 1.1. These frontages activities in combination lead to busy traffic flow. Furthermore, according on the accident report from Kuantan Police Traffic, road accident at the study location was increased from 69 cases to 181 cases 3 consecutive years from 2008 until 2010 as shown in Table 1.1.



**Figure 1.1:** Study Area (www.google.com)

**Table 1.1:** Accident report at study location  
(Balai Polis Trafik Kuantan, Pahang, 2008-2010)

YEAR	TOTAL ACCIDENTS
2008	69
2009	125
2010	181

Based on such issues, the TWSC unsignalized intersection of Jalan Semambu has been chosen in order to analyze the performance based on queue length and level of services. Hence, the effectiveness of existing TWSC unsignalized intersection can be determined whether it is effective or worst.

### 1.3 Objective

The main objectives of this study are:

- i. To determine critical gap results for unsignalized intersection in urban area.
- ii. To compare critical gap results obtained from field observation with those established in HCM.
- iii. To analysis the performance of unsignalized intersection in terms of queue and level of services based on critical gaps found from field studies and those established in HCM.

#### **1.4 Scope of Study**

In this study, two-way stop controlled unsignalized intersection of Jalan Semambu was selected as study location. This type of intersection is the most common type of unsignalized intersection especially in urban and suburban area. Based on police traffic report analysis, there are 69 until 181 road accidents that occur at the study location in period 3 years which is from 2008 until 2010. Furthermore, from my observation the unsignalized intersection is located near with Semambu Industrial Area and Sekolah Kebangsaan Semambu. It is show that the intersection is facing with the busy traffic flow because the uses land around the unsignalized intersection that has been chosen as study location.

Major parameter affecting the capacity and the performance of unsignalized intersection is the critical gap. The parameters are needed to be considered to analysis the unsignalized intersection. Basically, the critical gap at unsignalized intersection was established by HCM (Highway Capacity Manual). However, critical gaps also can be produced from field. In logically, critical gaps for each intersection are difference based on the geometry of the intersection and area located around the intersection. In this study, gap acceptance study was conducted on field to determine the actual value of critical gaps at the TWSC unsignalized intersection. Raff's method was used in determination of critical gap. The gap results obtained from field observation and those established by HCM were used as input data in Sidra software.

Several data collection was conducted at the beginnings which are the geometry layouts of unsignalized intersection such as number of lanes, lane width and others. Then, other parameters such as type of turning movements, traffic volume count movement and vehicle characteristics were observed. For this study, only passenger car were considered to minimize the scope of study. The data was collected during peak hour period which is the traffic volume is high, road accidents, delay and congestion are occurs during the time. The performance of the intersection was analyzing using Sidra software based on critical gaps found from field studies and those established in HCM. The software is one of micro-analytical traffic evaluation tool that are usually use by traffic engineer. From output produced by Sidra software, either critical gap obtained from field observation or established by HCM is more closed with actual condition can be determined. Therefore, the performance of the intersection can be analysis and evaluate in terms of queue and level of services (LOS). Hence, the solution or new alternative can be proposed to solve the identified problem.

## **1.5 Significance of Study**

The importance of the research is to analysis the performance of TWSC unsignalized intersection at study location based on gap acceptance. The critical gap is important parameter to know especially in analysis of unsignalized intersection. The critical gap of the TWSC unsignalized intersection are determined using Raff's method. From the output produced from Sidra software, the performance of unsignalized intersection was known in terms of queue and level of services (LOS). Hence, determination can be made either the critical gap was establizehd by HCM or critical gap obtained from field observation is more closed with actual field condition. If the output produced from Sidra software is closed with the HCM standard, it can be concluded that the critical gap that was proposed by HCM is valid and acceptable.

Then, from the analysis it can be determined either the TWSC unsignalized intersection is efficient or need improvement. In traffic it is very important elements to make the traffic flow smooth and effective. The importance of the intersection design is to ensure efficiency of operation, to maximize the capacity of intersection, to ensure the safety of road users as well as reduce intersection delays. The Sidra software analyzes the data and the output provides measure of effectiveness (MOEs) from which the performance of the roadway can be determined.

Based on the analysis, the new alternative way can be propose to solve the problem at the intersection such as increase the number of lane, propose traffic light, upgrading the geometry layout and others. The TWSC unsignalized intersection at the study area was analyzed by using the Sidra software .Hence, the traffic movement at the intersection become more safely and efficiently.

## CHAPTER 2

### LITERATURE REVIEW

#### **2.1 Introduction**

In chapter 1, overall contents of this study were discussed from the problem statement, objectives and the scope. In order to understand this study, the literature reviews on several procedures and the discussion on the parameters are carried out in this chapter. In this chapter, current literatures on the unsignalized intersection are reviewed in section 2.2. This section highlights the definition and importance of the unsignalized intersection in roadway elements. Sections 2.3 were discussed on parameters affecting the capacity such as priority of stream and conflicting traffic. Section 2.4 and 2.5 are discussed on major parameters need to be considered in analysis the unsignalized intersection such as gap acceptance and critical gap. Sections 2.6 were discussed about performance of TWSC unsignalized intersection which is queue and Level of Services (LOS). Finally, the applications of SIDRA software in conducting the analysis of an unsignalized intersection were discussed on last section in this chapter. In this section it was give a brief introduction about SIDRA software.



## 2.2 Overview of Unsignalized Intersection

Intersection is a major cause bottlenecks thus contributing to congestion. Various types of intersection are at-grade intersection, signalized and unsignalised intersection, and roundabout. Unsignalized intersections are most common intersection type but their capacity may be lower than other capacity. Furthermore, the intersections play an important part in the control of traffic flow in a network. At unsignalized intersection there are various types of movement like through movement on major street, right turn movement on major street, left turn movement on major street, through movement on minor street, and so forth. Each of these movements has a place in the hierarchy specifying their claim on the right way at the common intersecting space.

Traffic flow of a movement at unsignalized intersection is guided by the hierarchical position of the movement specified either by rules of driving or through static sign, such as 'STOP' or 'YIELD'. Unsignalized intersection were divided into two types which is two-way stop controlled (TWSC) and all-way stop controlled (ASWC) intersection. In this study, the unsignalized intersection was identified as two-way stop controlled unsignalized intersection. For TWSC unsignalized intersection, the stop controlled approaches are referred to as the minor road approaches. Minor road approaches usually are driveways or side streets that provide access to business or resident areas. Major road through traffic basically is in a free flow state, although the vehicles making right and left turns into the driveways or side streets have minor impacts on through traffic speed (HUAGUO ZHOU, 2006). J.L Gattis and Sonny T. Low defined a TWSC intersection is an unsignalized intersection with the right-of-way assigned to one of the two streets that intersect. The prioritized street is called the major street. Vehicles on the non-priority streets, also known as minor streets, must stop at the intersection. The other minor street approach is then named as the opposing approach (not applicable at a T-intersection). The two major street approaches are known as the conflicting approaches.



A poorly operating unsignalized intersection may affect a signalized network or operation of an Intelligent Transport System. The theory of the operation of unsignalized intersections is fundamental to many elements of theory used for other intersections. At an unsignalized intersection each driver must find a safe moment for the movement observing current traffic, traffic signs (stop or yield) and pertinent regulations (“right before left”) (Luttinen, 2004). According to HUAGUO ZHOU (2006), there are no delays for major road through traffic because it passes through unsignalized intersections. The delay of vehicles making right and left turns out of side streets are the main factors to determining the operational performance and level of services of the intersections.

Analysis procedure with respect to Malaysian road condition is needed to design the unsignalised intersection so the capacity is always greater than traffic demand. Currently, Malaysia has been adopting the United States Highway Capacity Manual 1985 (U.S. HCM 1985) (TRB, 1985) as the procedure to analyse the capacity for unsignalised intersection (Sanik, 2007).

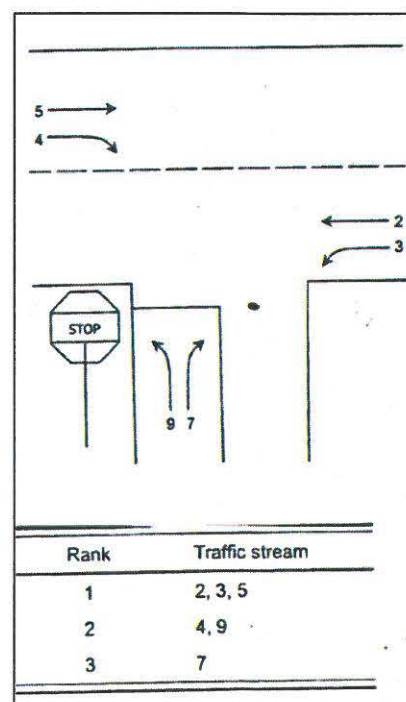
## **2.3 Parameters Affecting Capacity**

### **2.3.1 Priority of Stream**

The priority of stream at unsignalized intersection must be correctly identified. Some of the streams have absolute priority, while others have to give way or yield to higher rank stream. Figure 2.1 shows the comparative priority in the stream for two way stop control intersection. In the T-intersection, the priority of movement is described in three level ranks. Movement of rank 1 include through traffic on the major street and left turning from the major street. For movement 2, it includes right turning from the major street and left turning from the minor street. Then, for movement 3 it includes right turning from minor street. For four-leg intersection, the priority of movement is described in four level ranks.

However, most of the two way stop control at four leg intersections is upgraded to signalized intersection especially in urban area. The important criteria in priority stream are to identify the availability of gap. For example, if a right turning vehicle on the major street and turning vehicle from minor street are waiting cross the major stream, the first available gap of acceptable size would be taken priority to the right turn vehicle on the major street. The minor street turning traffic must wait for the next available gap.

The HCM 2000 defines a large number of such right turning and left turning vehicles could use up so many of the available gaps that minor street and would be severely impeded or unable to make safe crossing movements. At many unsignalized intersections, there is room in the center of the major street where several minor-street vehicles can be stored between the two directions of traffic flow on the major street, especially in the case of multilane major-street traffic. This storage space within the intersection enables the minor-street driver to pass each of the major-street streams one at a time, which can contribute to an increased capacity (Werner Brilon, 1999).

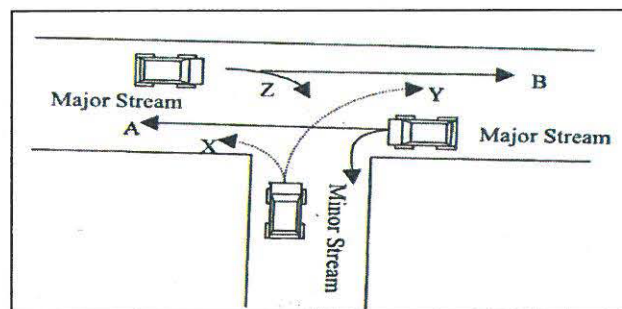


**Figure 2.1:** Traffic Stream at A Two Stop Control intersection (Malaysian HCM)

### 2.3.2 Conflicting Traffic

Each movement at two way stop control intersection faces a different set of conflicts that are related to the nature of movement computation of conflict flows. A typical unsignalized T-junction is as illustrated in Figure 2.2. There are six different types of traffic movements at the T-junction. The hierarchy of the unsignalized T-junction has three levels conflicting streams that should be considered. It is movement from Z, Y and X. The conflicting streams mean that the movements cannot cross the junction except the driver gives priority to other movement which has simple potential conflict and high saturation flow. Right turn movement from major road (movement Z), is the first conflicting streams because this movement is from the major stream where major stream is a priority stream that minor stream should be aware of it and must be given priority.

Second conflicting stream is left turn movement from minor stream. The last conflicting stream is right turn movement from minor stream. For left turn movement from minor stream, the driver has to give way only to movement 'A', but for right turn movement from minor stream, the driver has to give way movements 'A' 'B' and 'Z' which more complicated. Most traffic conflicts occur due to conflicting maneuvers at unsignalized intersections where design and operations are comprised of a complex set of parameters including number of traffic lanes, traffic volumes, spacing between intersections, medians, speed, and turning movements. The majority of access-related crashes have been attributed to left-turn movements. At unsignalized intersections, left turn movements from driveway to a major road pose many problems, and a large number of conflict points (Zhu Jian Lu, 2010).



**Figure 2.2:** Vehicles Movement at T-Junction TWSC (Malaysian HCM)

## 2.4 Gap Acceptance

Gap acceptance is a task that drivers perform so regularly that it occurs nearly at a subconscious level. However, being able to successfully complete this task is essential in order to drive safely. Not all drivers display the same gap acceptance behaviour and even same driver can react differently in different locations and under different conditions. Gap acceptance data can be collected and analyzed in a number of different ways. However, the principles of each method are quite similar. The best way to collect data on driver's gap acceptance behaviour is through direct field observations (M.Tupper, 2011).

When traffic is congested, drivers may choose to behave more aggressively and accept smaller gaps than is modelled by standard parameters. Existing condition may therefore be hard to reproduce unless more aggressive parameters are adopted. Currently, the most common way to observe gap acceptance behaviour in the field is to set up video surveillance equipment at the site and then process the data off-site. Processing the data generally involves slowly advancing the recording and capturing time stamps of each vehicle passing through the intersection. This is a very time consuming process, however the results are generally thought to be quite accurate.

Once the gap data was collected and analysed, curves representing the frequency of rejection and acceptance of gaps were developed. Based on Noel Kay (2006), the calculated gap acceptance parameters were applied in a micro simulation model and compared with observed travel times. These showed a better level of fit compared to the use than the default value. Hamed & S. M. Easa (1997) was defined gap acceptance is an important factor in evaluating delays, queue lengths, and capacities at unsignalized intersections (*Highway* 1994). Gap acceptance may also be used to predict the relative risk at intersections, where smaller gaps generally imply higher accident risk (Polus 1985).